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BROWN'S STAR ATLAS



SHOWING
ALL THE BRIGHT STARS
HOW TO FIND AND USE
FOR
NAVIGATIONAL PURPOSES

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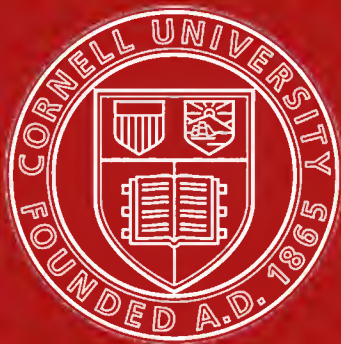
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BROWN'S STAR ATLAS,

SHOWING ALL THE BRIGHT STARS,

. . . WITH . . .

FULL INSTRUCTIONS HOW TO FIND AND USE THEM

. . . FOR . . .

NAVIGATIONAL 'PURPOSES

. . . AND . . .

BOARD OF TRADE EXAMINATIONS.



[Entered at Stationers' Hall.]

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PREFACE.

RECENT YEARS have witnessed a considerable development of interest in Stellar Navigation. This is due in some measure to the fact that it now forms an important feature of the Board of Trade examinations, but both the increased interest and its inclusion in the examinations are results of the further fact that its importance and necessity are becoming more clearly recognised, and that it is now acknowledged to be an essential factor in the navigation of modern vessels.

This atlas is intended for the use and guidance of those who wish to be able to recognise the principal BRIGHT stars, and to become proficient star navigators; and while it is of interest to those going up for examination, it is essentially a book for practical use at sea.

PART I. is designed to help beginners to trace out the principal constellations and BRIGHT stars. The six large maps show all the BRIGHT stars projected on the plane of a meridian, and may be used by observers in any latitude. A study of these maps not only facilitates the recognition of the stars, but also fixes in the mind an approximate knowledge of their positions in the heavens, and of the times when they are available for observation. The fact that the maps are continuous, and show in unbroken succession all the BRIGHT stars, is believed to be a good feature. In addition to this the principal constellations are further illustrated on special maps. The maps have been drawn by Mr. DENNING, F.R.A.S.

PART II. deals with the use of the stars in practical navigation, and the various methods of finding a ship's position, and the deviation of the compass are explained.

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HONOURS MEDALLIST IN NAUTICAL ASTRONOMY.

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PART I.

HOW TO FIND THE STARS.

Explanation of the maps, and directions for tracing and recognising the principal constellations and bright stars.

THE MAPS are designed in such a manner that sections of the heavens are presented for observation in rotation.

On each map the central portion is the part specially presented for study, and is printed with white stars on a dark ground, this being most striking to the eye. Each of these sections shows a portion of the heavens from Pole to Pole, included between Meridians, 4 hours or 60° apart. The whole firmament thus occupies six maps.

On each side of these sections, for convenience of reference, the stars in the adjacent regions of the heavens are shown. To avoid overcrowding the maps, only the brighter stars, or those used in navigation, appear.

The observer must imagine himself to be holding the map overhead and looking at it from below, the North point of the map being directed to the North. The central North and South line then represents the meridian, and he will easily understand that the right hand half of each map represents the Western part of the heavens, and the left hand portion the Eastern part.

It is not possible to represent the celestial sphere on a plane surface such as a map, and at the same time to preserve the relative distances and bearings of all the stars from each other. In all maps of the stars there must be a certain amount of distortion or misplacement; only on a globe can their relative positions be accurately illustrated. In the method of projection here chosen the apparent misplacement is least in the central portion of the maps, and this is the reason that attention is directed to that part. Otherwise the whole heavens might have been presented on two maps only.

As the position of a place on the earth's surface is fixed by its *Latitude* and *Longitude*, so the position of a point in the celestial sphere is fixed by its *Right Ascension* and *Declination*.

The Declination of any object is its angular distance North or South of the Equinoctial or Celestial Equator, measured along the meridian. It thus corresponds to *Latitude* on the earth's surface. On the maps the Equinoctial is the line through the centre from East to West.

The Right Ascension of a celestial object is the arc of the Equinoctial between the first point of Aries and the meridian of the object, always reckoning eastward from the first point of Aries. It thus corresponds to *Longitude* on the earth, but differs in the manner in which it is reckoned; for, whilst longitude is reckoned East and West of the meridian of Greenwich, Right Ascension is reckoned in only one direction, viz., eastward from 0 to 24 hours, or 360° . Therefore, when we say a star's Right Ascension is 2 hours, or 13 hours, etc., we mean that it is on a meridian 2 hours or 13 hours, etc., East of the first point of Aries. It is usual to express R.A. in time, and, when looking South, R.A. will increase to the left. On the large maps meridians are drawn for each hour.

NOTE.—The first point of Aries is the point where the sun's centre crosses the Equinoctial when passing from South to North Declination. It is not marked in the heavens by any star. On Map I. it is indicated by the point on the Equinoctial where the 0 or 24 hours meridian crosses it.

Naming of Stars.

Constellations.—A Constellation consists of a number of stars grouped under one name. These names have been handed down from the earliest days of astronomy. The stars belonging to a constellation are distinguished by prefixing to each one a letter of the Greek alphabet. Thus we have α Orionis, β Orionis, α Ursæ Majoris, etc. The constellation names are printed in capitals on the maps. Some of the principal constellations are also shown on special maps, with the Greek letters attached to each star.

In addition to the above style of distinguishing stars most of the principal stars have been given proper names; thus α Orionis is also named BETELGUESE, α Ursæ Majoris is known as DUBHE, and so on. These names are printed on the maps in smaller type, but only the more familiar ones have been given, so as to avoid overcrowding the maps with names. A full list of the names will be found on page 4.

Magnitudes of Stars.

The magnitude or brilliancy of each star is indicated by a number, and the brighter the star, the less this number will be. The magnitude numbers are now given to tenths, that is, to one decimal figure (*see* Table of Stars), and a star of magnitude 1.5 is one-tenth of a magnitude brighter than one of magnitude 1.6.

Two of the stars are so bright that their magnitudes are denoted by minus numbers, as they are brighter than magnitude 0. Sirius, the brightest of the fixed stars, is of magnitude -1.4 . Canopus is next in brilliancy with magnitude -1.0 .

Stars that do not rise above the Observer's Horizon.

If an observer's *latitude* and a star's *declination* have *different names* and their *sum exceeds* 90° , the star will not rise above the horizon in that latitude. This can

**Mean Right Ascension and Declination of Fixed Stars for January 1, 1904,
and maps on which they appear.**

	Star's Name.	Mag.	Right Ascension.			Annual Change.	Declination.			Annual Change.	
			h.	m.	s.	s.		"	"	"	
STARS ON MAP I.	α Andromedæ (<i>Alpherat</i>),	2.1	0	3	25	+ 3	N.	28	33	38	+ 20
	γ Pegasi (<i>Algenib</i>),	2.9	0	8	17	+ 3	N.	14	39	0	+ 20
	β Ceti (<i>Diphda</i>),	2.2	0	38	46	+ 3	S.	18	30	48	+ 20
	β Andromedæ (<i>Mirach</i>),	2.4	1	4	21	+ 3	N.	35	6	42	+ 19
	α Ursæ Min. (<i>Polaris</i>),	2.1	1	24	15	+ 26	N.	88	47	42	+ 19
	α Eridani (<i>Achernar</i>),	0.5	1	34	8	+ 2	S.	57	43	28	+ 18
	α Arietis (<i>Hamal</i>),	2.2	2	1	46	+ 3	N.	23	0	31	+ 17
	α Ceti (<i>Menkar</i>),	2.8	2	57	16	+ 3	N.	3	42	48	+ 14
	β Persei (<i>Algol</i>),	(var.)	3	1	55	+ 4	N.	40	35	10	+ 14
	α Persei (<i>Mirfak</i>),	1.9	3	17	28	+ 4	N.	49	31	12	+ 13
STARS ON MAP II.	α Tauri (<i>Aldebaran</i>),	1.1	4	30	25	+ 3	N.	16	19	0	+ 8
	α Aurigæ (<i>Capella</i>),	0.2	5	9	36	+ 4	N.	45	54	3	+ 4
	β Orionis (<i>Rigel</i>),	0.3	5	9	55	+ 3	S.	8	18	44	+ 4
	γ Orionis (<i>Bellatrix</i>),	1.7	5	19	59	+ 3	N.	6	15	47	+ 3
	β Tauri (<i>Nath</i>),	1.8	5	20	13	+ 4	N.	28	31	36	+ 3
	ϵ Orionis (<i>Alnilam</i>),	1.7	5	31	21	+ 3	S.	1	15	46	+ 2
	ζ Orionis (<i>Alnitak</i>),	2.0	5	35	55	+ 3	S.	1	59	35	+ 2
	α Orionis (<i>Betelgeuse</i>),	(var.)	5	49	58	+ 3	N.	7	23	22	+ 1
	η Geminorum,	(var.)	6	9	5	+ 4	N.	22	32	6	- 1
	α Argûs (<i>Canopus</i>),	-1.0	6	21	49	+ 1	S.	52	38	35	- 2
	α Canis Majoris (<i>Sirius</i>),	-1.4	6	40	55	+ 3	S.	16	35	2	- 4
	ϵ Canis Majoris (<i>Adara</i>),	1.6	6	54	51	+ 2	S.	28	50	28	- 5
	δ Canis Majoris (<i>Wezen</i>),	2.0	7	4	29	+ 2	S.	26	14	26	- 6
	α^2 Geminorum (<i>Castor</i>),	2.0	7	28	29	+ 4	N.	32	5	59	- 8
	α Canis Min. (<i>Procyon</i>),	0.5	7	34	17	+ 3	N.	5	28	15	- 8
	β Geminorum (<i>Pollux</i>),	1.2	7	39	27	+ 4	N.	28	15	30	- 8
STARS ON MAP III.	ϵ Argûs,	1.7	8	20	33	+ 1	S.	59	12	2	- 12
	δ Argûs,	2.0	8	42	3	+ 2	S.	54	21	24	- 13
	β Argûs,	1.7	9	12	9	+ 1	S.	69	19	18	- 15
	α Hydræ (<i>Alphard</i>),	2.2	9	22	52	+ 3	S.	8	14	32	- 16
	α Leonis (<i>Regulus</i>),	1.3	10	3	16	+ 3	N.	12	26	12	- 18
	α Ursæ Majoris (<i>Dubhe</i>),	2.0	10	57	49	+ 4	N.	62	16	10	- 19
	β Leonis (<i>Denebola</i>),	2.2	11	44	10	+ 3	N.	15	6	31	- 20
STARS ON MAP IV.	γ Ursæ Majoris (<i>Phecda</i>),	2.5	11	48	47	+ 3	N.	54	13	43	- 20
	α^1 Crucis (<i>Southern Cross</i>),	1.0	12	21	15	+ 3	S.	62	34	1	- 20
	γ Centauri,	2.4	12	36	13	+ 3	S.	48	25	58	- 20
	β Crucis,	1.5	12	42	6	+ 3	S.	59	9	51	- 20
	ϵ Ursæ Majoris (<i>Alioth</i>),	1.8	12	49	48	+ 3	N.	56	28	51	- 20
	α Virginis (<i>Spica</i>),	1.2	13	20	8	+ 3	S.	10	39	37	- 19
	η Ursæ Majoris (<i>Benetnasch</i>),	1.9	13	43	46	+ 2	N.	49	47	32	- 18
	β Centauri,	0.8	13	57	3	+ 4	S.	59	54	36	- 17
	θ Centauri,	2.1	14	1	2	+ 4	S.	35	53	52	- 17
	α Boötis (<i>Arcturus</i>),	0.3	14	11	17	+ 3	N.	19	40	55	- 17
	α^2 Centauri,	1	14	33	5	+ 5	S.	60	26	13	- 16
	β Ursæ Minoris (<i>Kochab</i>),	2.2	14	50	59	- 0	N.	74	32	52	- 15
STARS ON MAP V.	β Libræ (<i>Zubenelg</i>),	2.8	15	11	50	+ 3	S.	9	1	44	- 13
	α Coronæ (<i>Alphacca</i>),	2.3	15	30	37	+ 3	N.	27	2	15	- 12
	α Serpentis (<i>Unuk</i>),	2.8	15	39	32	+ 3	N.	6	43	39	- 12
	δ Scorpii,	2.5	15	54	39	+ 4	S.	22	20	56	- 10
	α Scorpii (<i>Antares</i>),	1.3	16	23	31	+ 4	S.	26	13	9	- 8
	α Triang. Aust.,	1.9	16	38	30	+ 6	S.	68	51	7	- 7
	ϵ Scorpii,	2.3	16	43	57	+ 4	S.	34	7	10	- 7
	η Ophiuchi,	2.6	17	4	52	+ 3	S.	15	36	23	- 5
	λ Scorpii,	1.8	17	27	5	+ 4	S.	37	2	2	- 3
	α Ophiuchi (<i>Ras-al-Hague</i>),	2.1	17	30	29	+ 3	N.	12	37	46	- 3
STARS ON MAP VI.	ϵ Sagittarii (<i>Kaus Australis</i>),	1.9	18	17	48	+ 4	S.	34	25	49	+ 2
	α Lyræ (<i>Vega</i>),	0.1	18	33	41	+ 2	N.	38	41	39	+ 3
	σ Sagittarii,	2.1	18	49	19	+ 4	S.	26	24	59	+ 4
	α Aquilæ (<i>Altair</i>),	0.9	19	46	6	+ 3	N.	8	36	52	+ 9
	α Pavonis,	2.0	20	18	3	+ 5	S.	57	2	35	+ 11
	α Cygni (<i>Deneb</i>),	1.3	20	38	10	+ 2	N.	44	56	13	+ 13
	α Cephei (<i>Alderamin</i>),	2.6	21	16	17	+ 1	N.	62	10	43	+ 15
STARS ON MAP VI.	ϵ Pegasi (<i>Enif</i>),	2.5	21	39	28	+ 3	N.	9	26	5	+ 16
	α Gruis,	1.9	22	2	11	+ 4	S.	47	25	34	+ 17
	α Pis. Aus. (<i>Fomalhaut</i>),	1.3	22	52	21	+ 3	S.	30	7	52	+ 19
	α Pegasi (<i>Markab</i>),	2.6	22	50	50	+ 3	N.	14	41	19	+ 19

be seen by inspection from the maps, as the parallels are drawn for every 10° ; therefore, if from the observer's latitude to the position of the star is over 90° , it will not appear above his horizon.

Stars that are always above the Horizon, or Circumpolar Stars.

If the observer's *latitude* and a star's *declination* have the *same name* and their *sum exceeds* 90° , that star will *always* be above the horizon, describing a circle round the elevated pole of the heavens.

The two last rules may conveniently be put thus :—subtract your latitude from 90 and thus get the co-latitude. *All stars in the opposite hemisphere with declination greater than the co-latitude will not rise above the horizon, and all stars in the same hemisphere with declination greater than co-latitude will be circumpolar, that is, will describe a circle round the pole always above the horizon.*

In London (latitude about $51\frac{1}{2}^\circ$ N., co-latitude $38\frac{1}{2}^\circ$) all stars in the Southern Hemisphere with declination greater than $38\frac{1}{2}^\circ$ will always be below the horizon, and all stars in the Northern Hemisphere with declination greater than $38\frac{1}{2}^\circ$ will be circumpolar. It must be noted here that stars seldom become visible until 5° or so above the horizon.

On the following page is a Table giving the times on certain dates when the stars on the central portion of each map are near the meridian. Every day each star crosses the meridian about 4 minutes earlier than on the preceding day, that is, roughly, about 2 hours earlier per month. Stars, therefore, which are near the meridian on any date, will occupy the same position about 2 hours earlier on the same day of the following month.

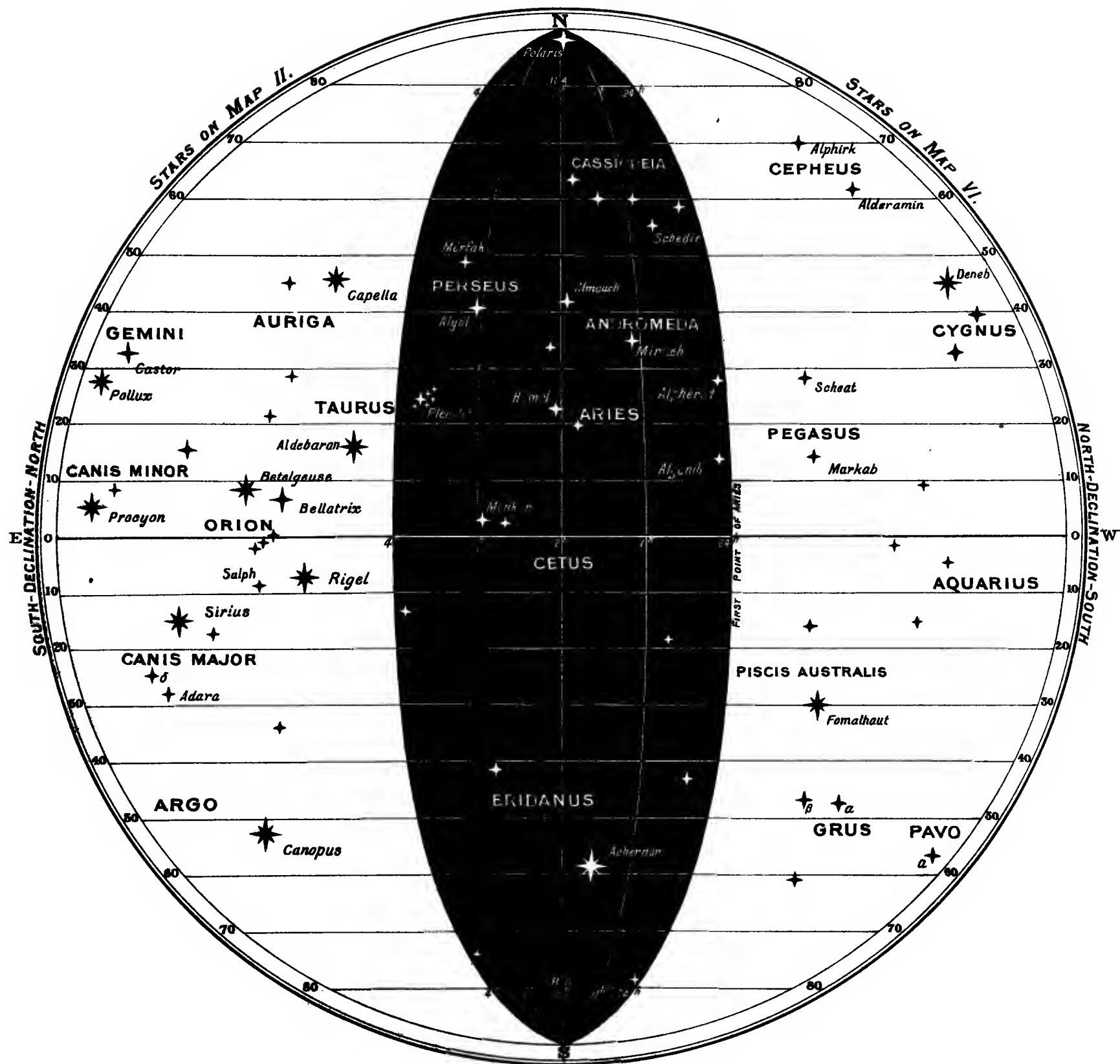
When comparing the maps with the sky, regard must be had to the observer's latitude, and to the rules for stars above the horizon as given.

Table showing the times when the stars on each map are near the meridian on certain dates.

	4hrs. A.M.	2hrs. A.M.	MIDNIGHT.	10hrs. P.M.	8hrs. P.M.
Map I.	August 22	September 22	October 22	November 22	December 22
„ II.	October „	November „	December „	January „	February „
„ III.	December „	January „	February „	March „	April „
„ IV.	February „	March „	April „	May „	June „
„ V.	April „	May „	June „	July „	August „
„ VI.	June „	July „	August „	September „	October „

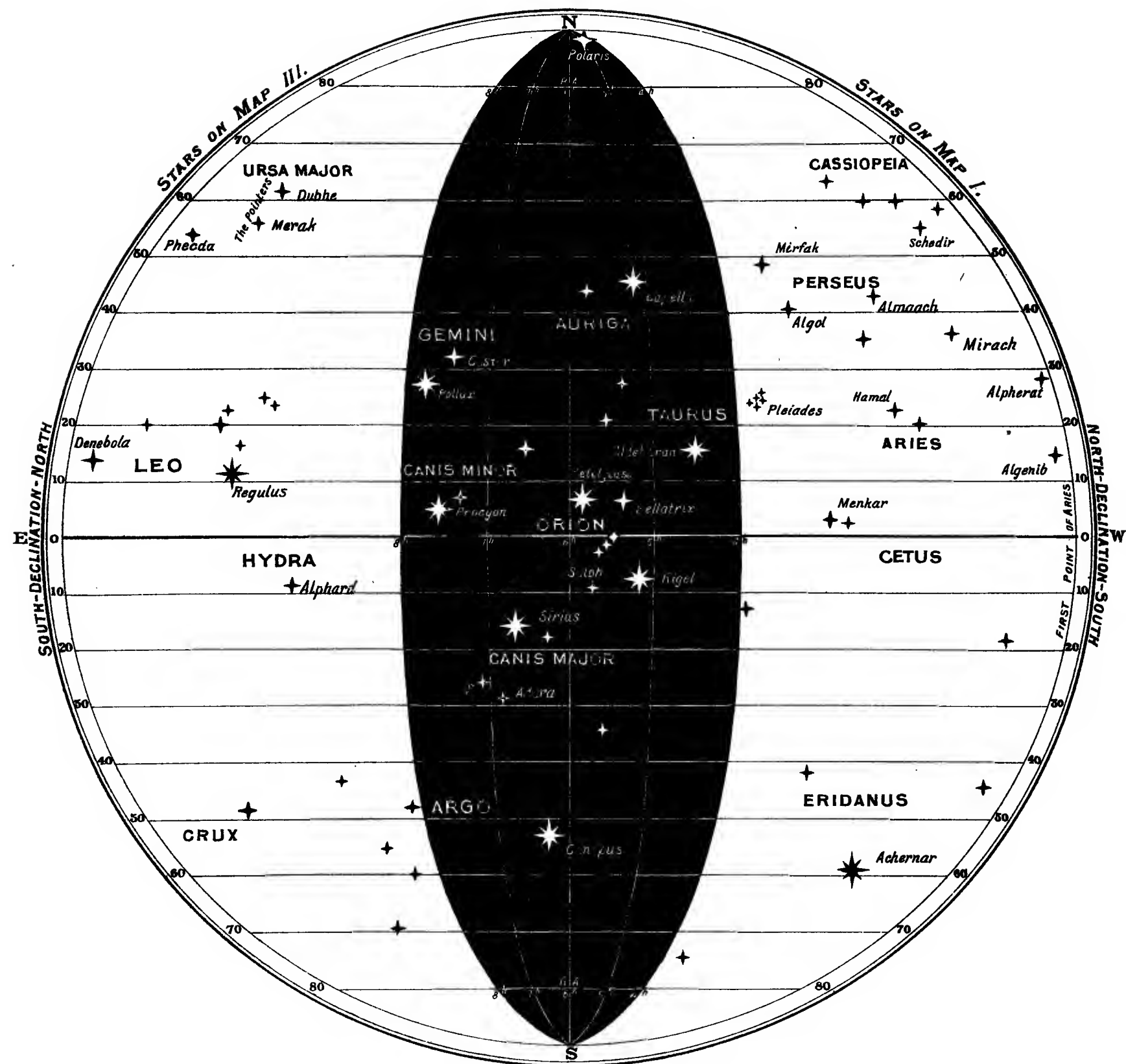
From the above Table the student should not have much difficulty in selecting the particular maps which show the stars near the meridian at any time of the day throughout the year.

MAP I.



*The Central Portion shows the Stars between R.A. 0hrs. (or 24hrs.), and R A. 4hrs.
Towards the end of October they will be near the Meridian at Midnight, and in the eastern part of the sky about 8 p.m*

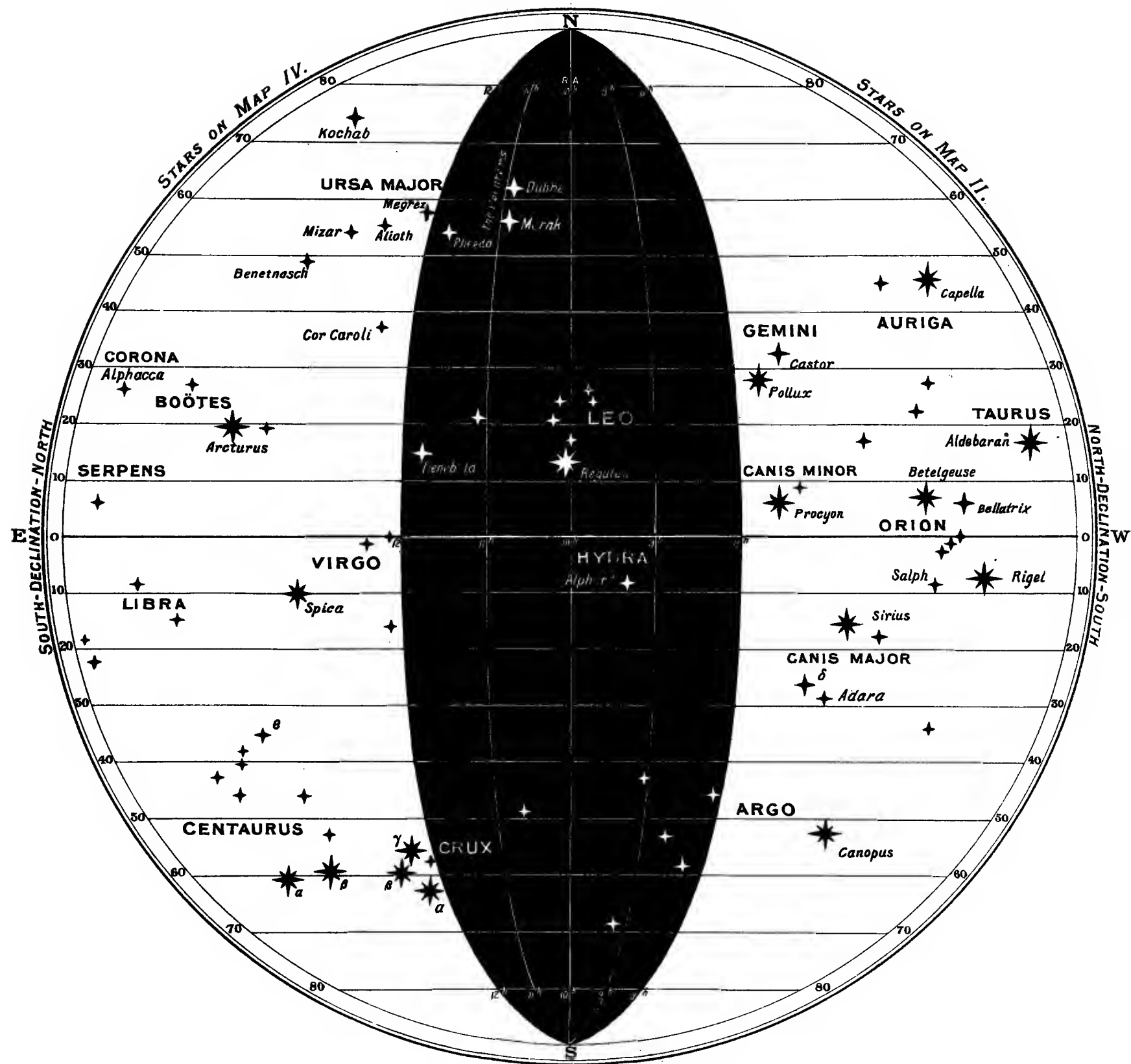
MAP II.



The Central Portion shows the Stars between R.A. 4hrs. and R.A. 8hrs.

Towards the end of December they will be near the Meridian at Midnight, and in the eastern part of the sky at 8 p.m

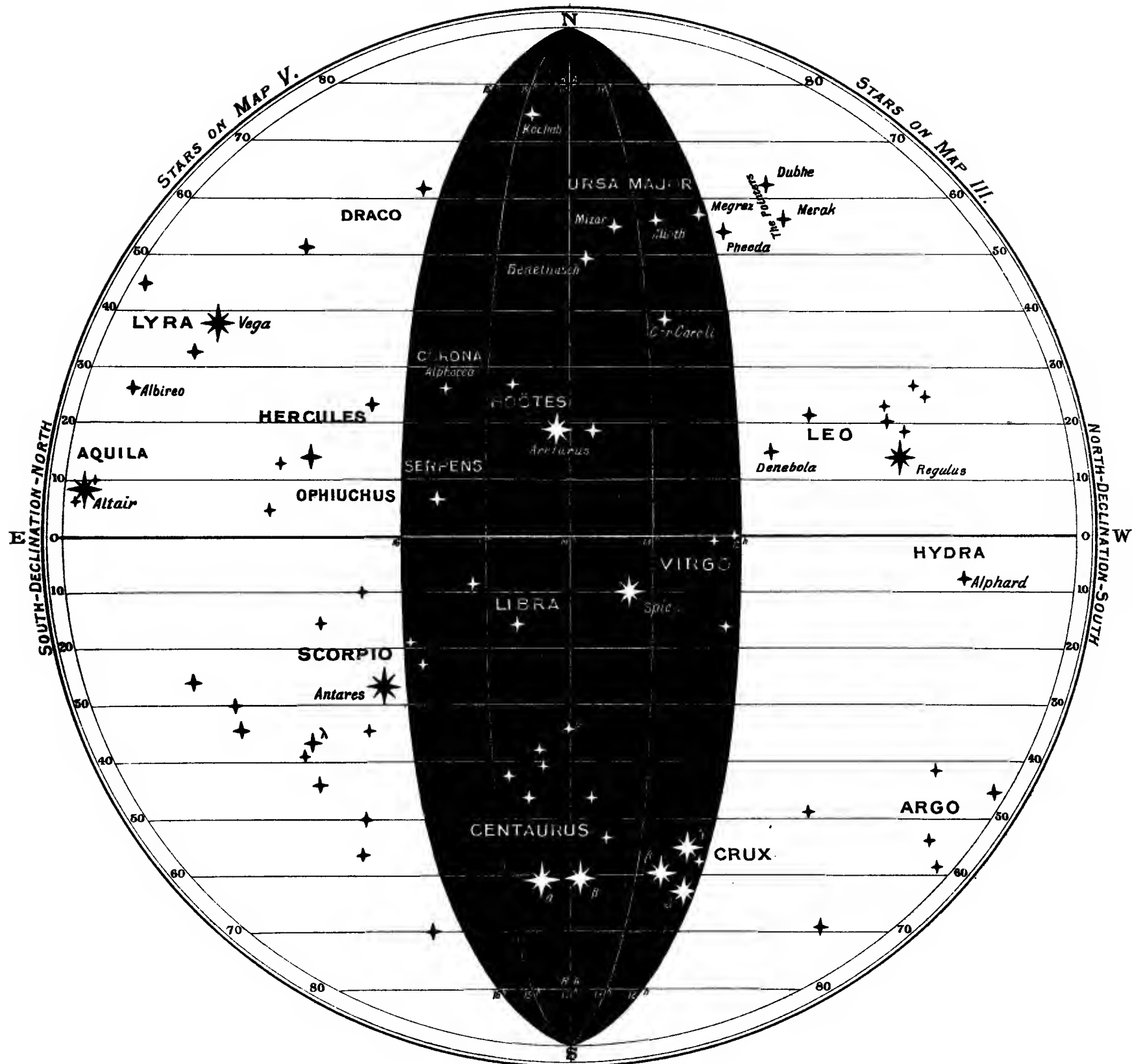
MAP III.



The Central Portion shows the Stars between R.A. 8hrs. and R.A. 12hrs.

Towards the end of February they will be near the Meridian at Midnight, and in the eastern part of the sky at 8 p.m.

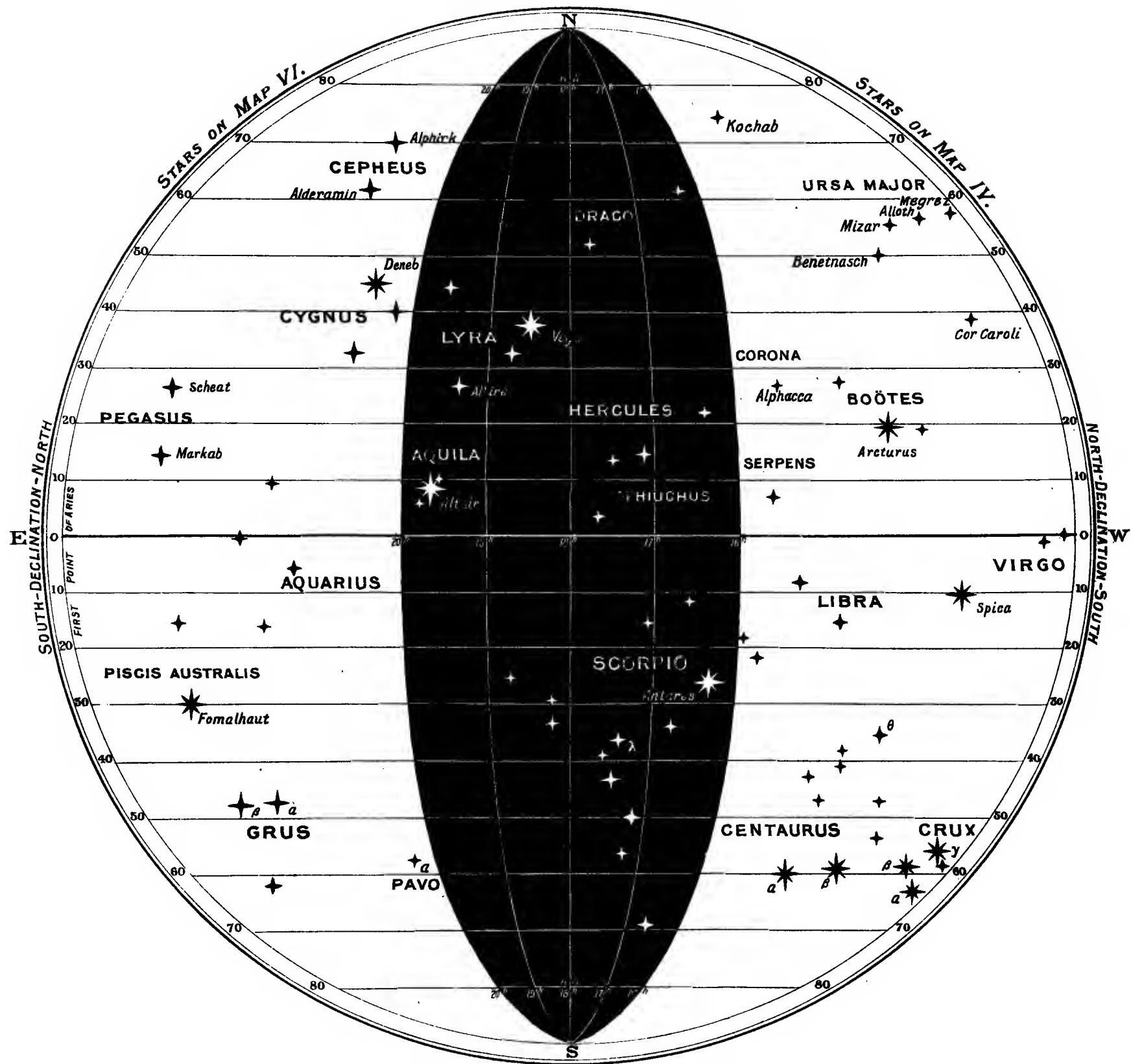
MAP IV.



The Central Portion shows the Stars between R.A. 12hrs. and R.A. 16hrs.

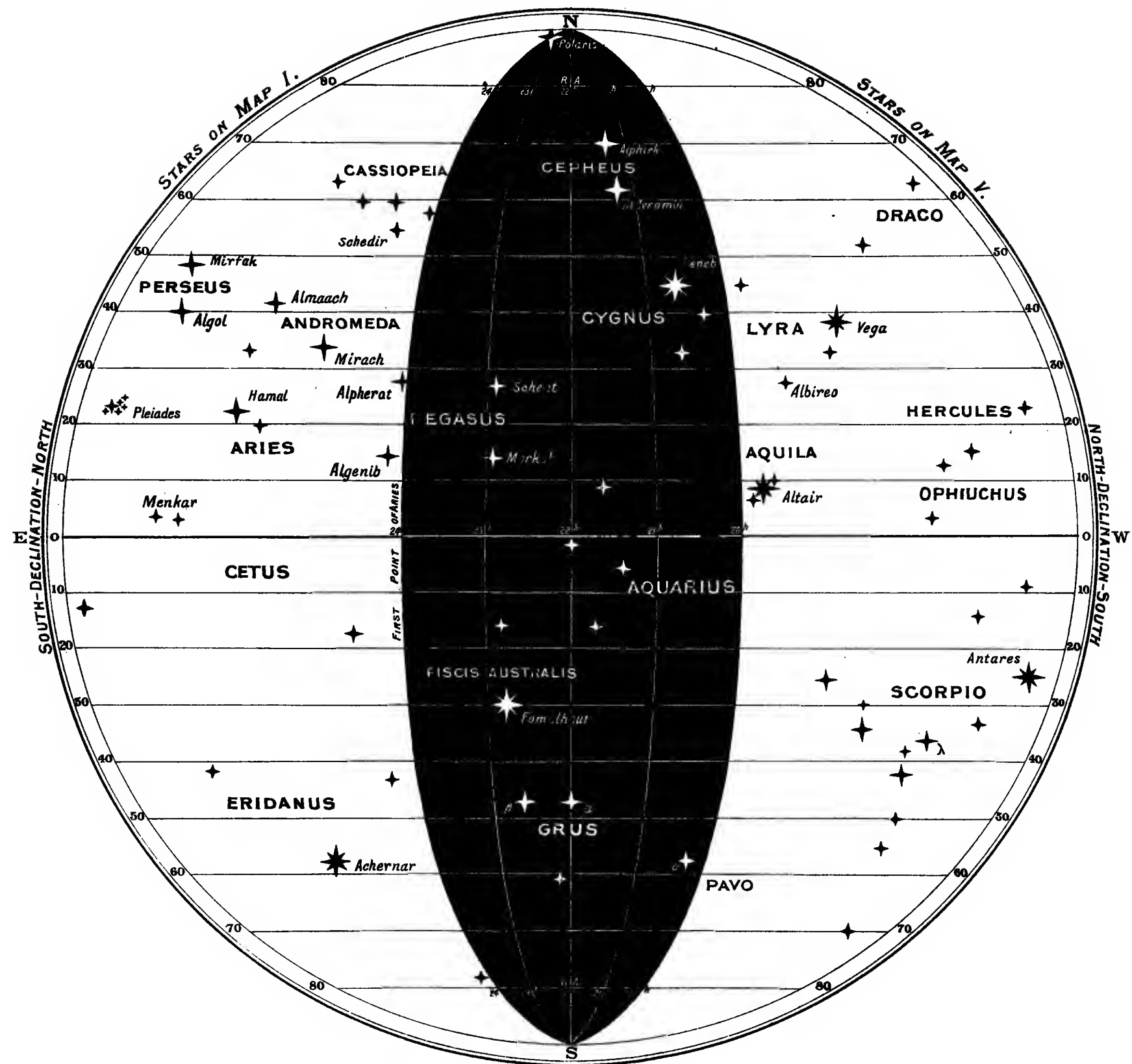
Towards the end of April they will be near the Meridian at Midnight, and in the eastern part of the sky at 8 p.m.

MAP V.



The Central Portion shows the Stars between R.A. 16hrs. and R.A. 20hrs.
Towards the end of June they will be near the Meridian at Midnight, and in the eastern part of the sky at 8 p.m.

MAP VI.



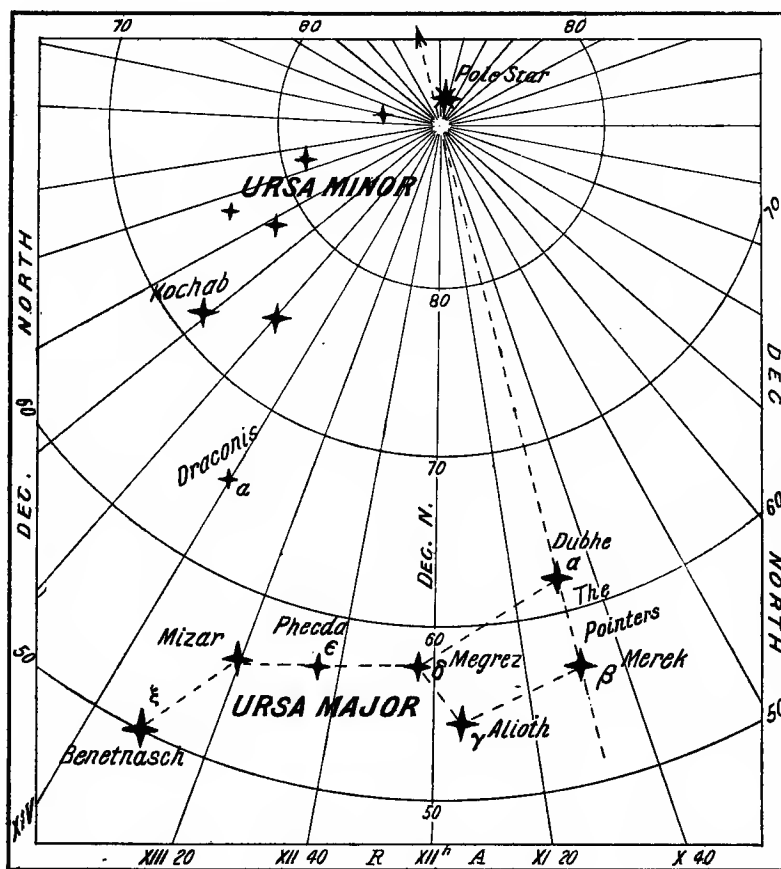
*The Central Portion shows the Stars between R.A. 20hrs. and R.A. 24hrs.
Towards the end of August they will be near the Meridian at Midnight, and in the eastern part of the sky at 8 p.m.*

How to trace the Principal Constellations and Bright Stars.

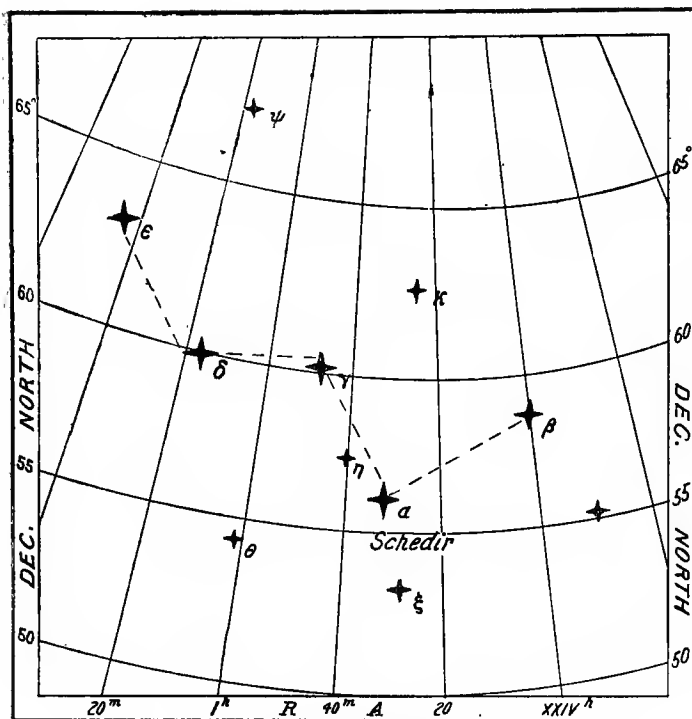
No attempt will be made here to confuse the mind of the reader with long and elaborate directions. It will be sufficient to briefly indicate how the principal bright stars in the various constellations may be identified. With the position of these established in his mind as leading marks in different parts of the heavens, methods of distinguishing or tracing others will suggest themselves to the observer as he studies the stars in the sky.

URSA MAJOR (The Great Bear).

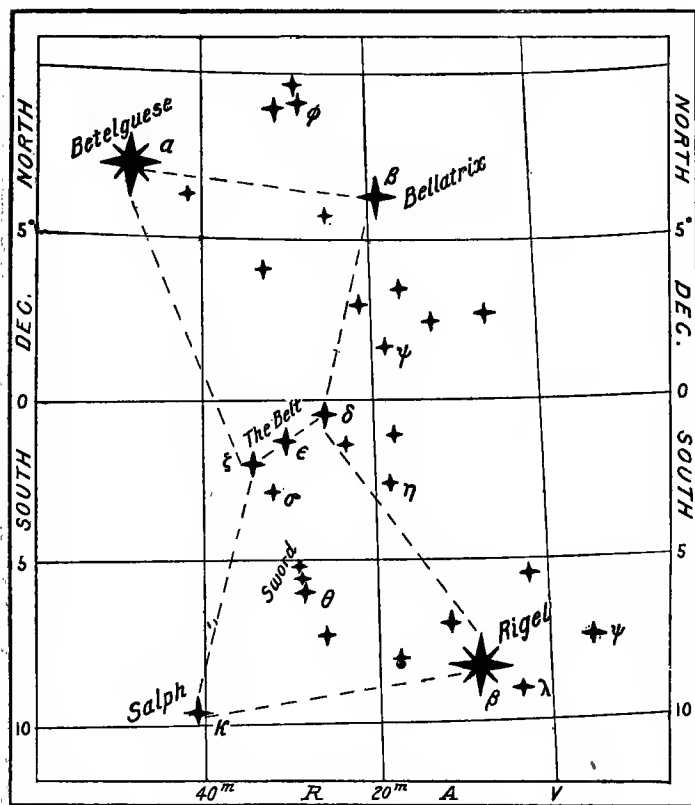
It will be convenient to begin with this constellation. It is specially illustrated on the adjoining small map. To observers in a higher latitude than about 45° N., this constellation is always visible on clear nights, being circumpolar. The two stars α (or *Dubhe*) and β (or *Merak*) are called the "Pointers," because they point almost directly to the North Star.



See also Large Maps III. and IV.



See also Large Map I.



See also Large Map II.

CASSIOPEIA.

On the opposite side of the Pole Star, but a little nearer to it than Ursa Major, is the smaller constellation CASSIOPEIA, also visible on all clear nights to observers in a higher North latitude than 45° . When URSA MAJOR is above the Pole Star, CASSIOPEIA is below it, and *vice versa*.

To obtain a view of these constellations as they appear when below the Pole, hold the small maps straight before you, facing North, instead of overhead.

ORION.

The most casual observer of the stars could not fail to notice this constellation when visible. The stars forming it lie on both sides of the Equinoctial, and within 10° of it. They therefore rise well above the horizon in all navigable latitudes. The three smaller stars in line with each other just South of the Equinoctial are called "Orion's Belt."

In line with these, and nearly equidistant in opposite directions,

are the bright stars *Aldebaran* and *Sirius* (see large map II.)—the former to the N.W., and *Sirius* (the brightest of all fixed stars) to the S.E.

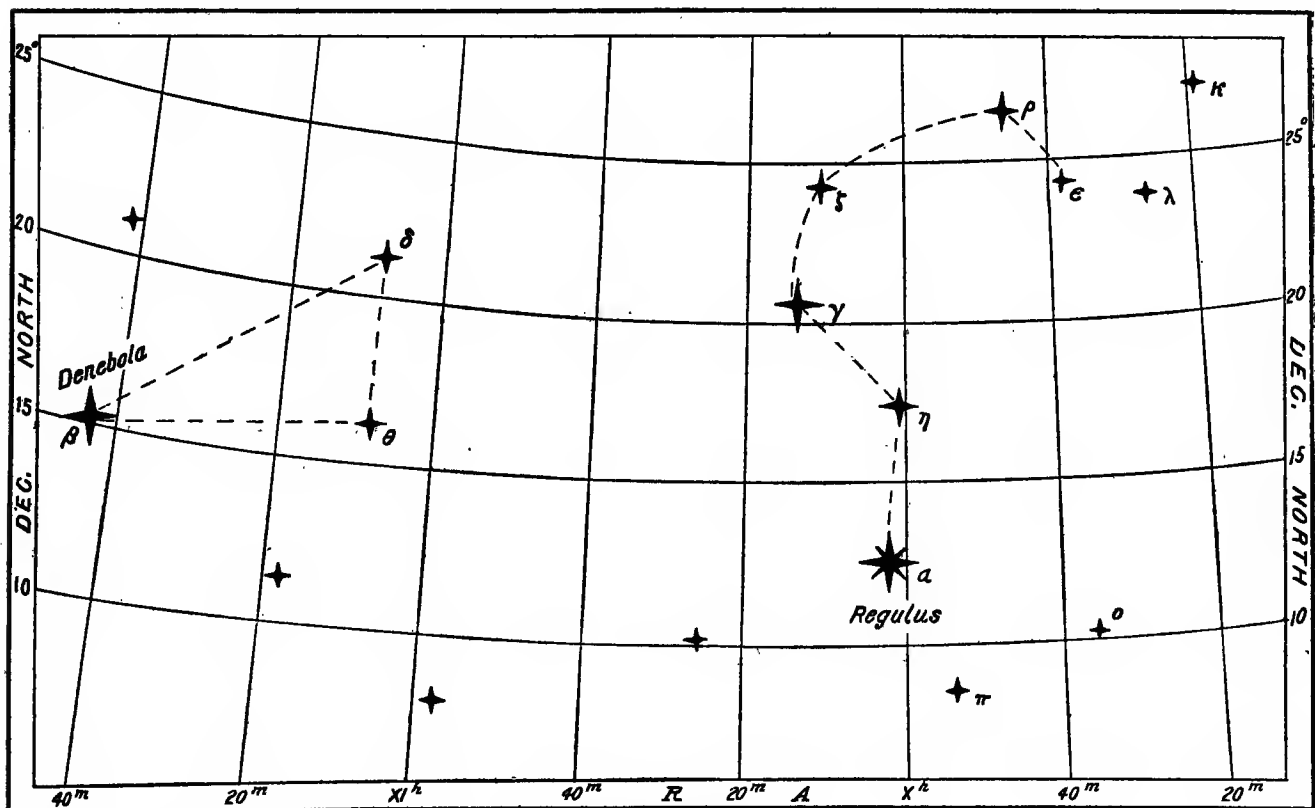
In the same direction as, but further from the Belt than *Aldebaran*, is a notable cluster of small stars named the *Pleiades*. These, though not actually useful for the purpose of navigation, afford a conspicuous mark for distinguishing neighbouring stars.

The bright stars *Procyon*, *Betelgeuse*, and *Sirius* form an almost equilateral triangle, *Procyon* being to the Eastward of the others. Nearly due North from *Procyon*, and about 23° from it, are the two stars *Castor* and *Pollux*.

LEO.

This constellation may be found by following the "Pointers" in the Great Bear backwards, that is, in a direction opposite to the Pole Star.

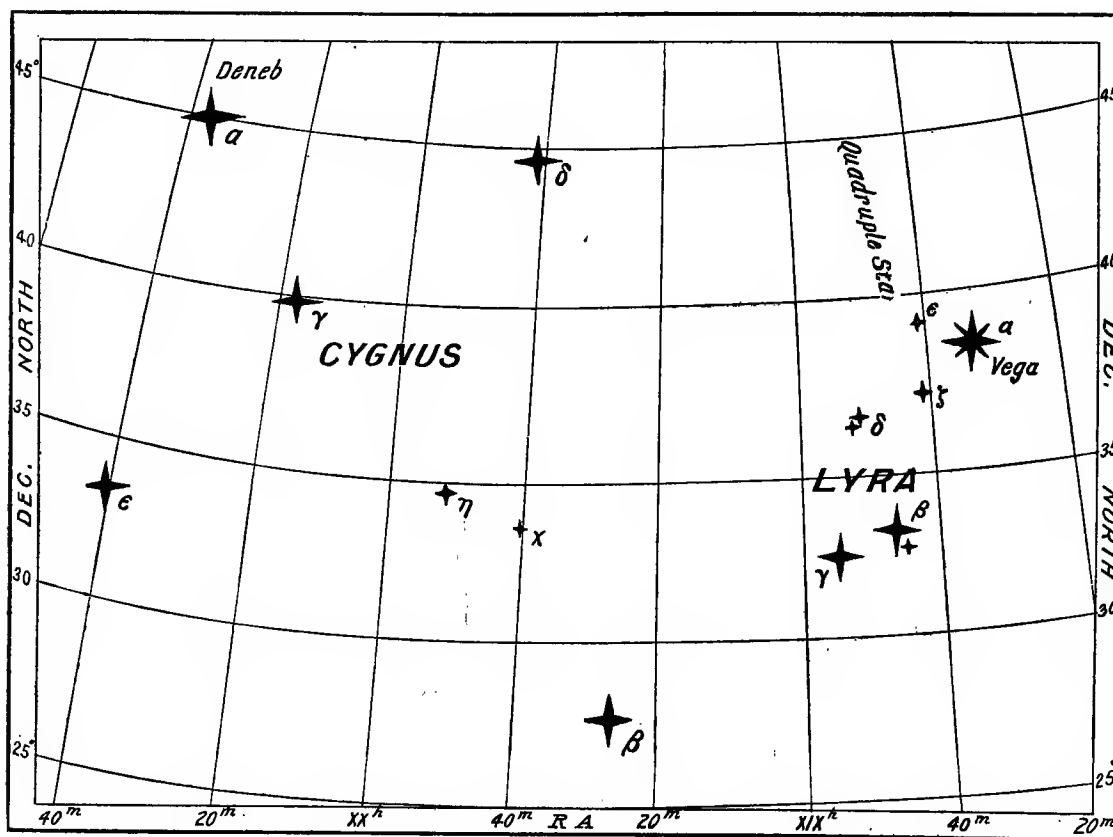
There is one very bright star in this group, viz., *Regulus* or α Leonis, and it is nearly equidistant from *Procyon* and *Pollux*, and to the Eastward of them. Some of



See also Large Map IV.

the stars in LEO form the outline of a sickle, with *Regulus* at the handle. Three other stars form a right-angled triangle. β Leonis (*Denebola*), *Arcturus*, and *Spica* form an almost equilateral triangle (*see* large map IV.)

CYGNUS and LYRA.



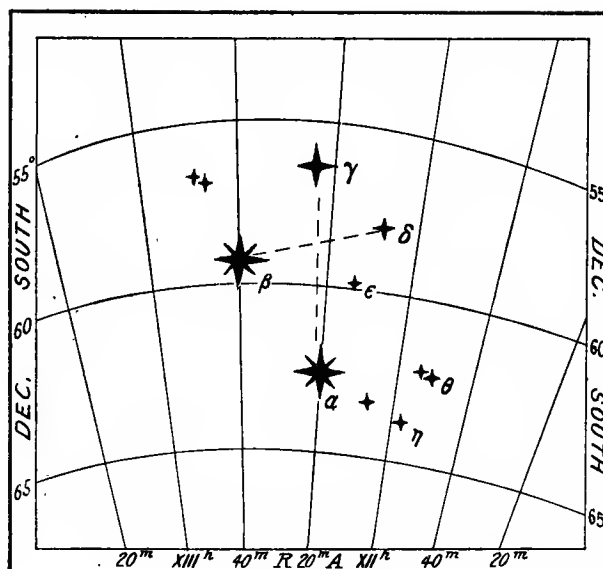
See also Large Map V.

The principal star in LYRA is *Vega*, which may on a clear night be distinguished from the fact that it is the most brilliant star in this part of the heavens. From *Vega*, *Deneb* or α Cygni may be traced, also *Altair* (α Aquilæ) by comparing with map V. or VI.

A very useful way of identifying stars and planets by taking meridian altitudes, is explained further on.

CRUX
(The Southern Cross).

There is no difficulty in identifying this constellation when above the horizon in the southern hemisphere. Near it are the two stars α and β in CENTAURI.



THE PLANETS.

Hitherto attention has been directed to the *fixed* stars only. The relative positions of these with respect to each other, as seen from the earth, do not appreciably change, hence they are termed *fixed* stars.

The planets (or wandering stars) are a number of bodies which revolve in orbits round the sun. Our own earth is one of these bodies, and the positions of the other planets as seen by us are constantly changing. The sun, together with the bodies which describe orbits round it, make up what is called the Solar System.

The fixed stars are at such an inconceivably immense distance from the Solar System, that, by comparison, the planets and the sun are relatively quite close to each other. The distance of the earth from the sun is calculated to be about 93,000,000 (ninety-three millions) of miles. This, of itself, is a distance which the mind cannot realise, but it shrinks into insignificance when compared with the distance of the nearest fixed star. To an imaginary observer on the nearest star this 93,000,000 of miles would only subtend an angle of about half-a-second of arc.

The planets are not self-luminous bodies as are the sun and fixed stars. Their brightness is due to the light of the sun, which they reflect, resembling in this respect the moon.

The principal planets are eight in number. Their names, arranged in order of their distances from the sun, are *Mercury*, *Venus*, *Earth*, *Mars*, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*.

The navigator will find *Venus*, *Mars*, *Jupiter*, and *Saturn* most useful, and the R.A. and Declination of these four are given for every day in *Brown's Nautical Almanac*.

The orbit of *Venus** round the sun is inside that of the earth. In consequence of this *Venus* appears to us to move from one side of the sun to the other, but never recedes further from it than about 47° . When the R.A. of *Venus* exceeds that of the sun it will (if not too near it) become visible after sunset. If the R.A. of *Venus* is less than that of the sun it will not be visible in the evening, but before sunrise in the morning.

The brilliancy of the planets varies with their position. Venus and Jupiter are so brilliant generally as to surpass the magnitude of any star. The twinkling or flickering of the fixed stars is familiar to all, and at times this twinkling is more apparent than at others. The planets do not twinkle so strongly as the stars; they shine with a much steadier light, and this fact helps the observer to distinguish them from the fixed stars.

The position of a planet amongst the stars may be found at any time by taking its R.A. and Declination from the *Nautical Almanac* for the current date, and marking this point on one of the star maps, it can then be seen where it is situated amongst the stars.

It is interesting to observe the motion of the planets when they are visible, from night to night amongst the fixed stars.

*The orbit of *Mercury* is also inside that of the earth, but being so near to the sun is not often visible to the naked eye.

PART II.

STAR PROBLEMS—WITH EXAMPLES.

Right Ascension of the Meridian (R.A.M.) or Sidereal Time at Ship.

THE SIDEREAL TIME at any place is the Westerly hour angle of the first point of Aries, and is identical with the Right Ascension of the Meridian.

It is important in dealing with star problems to be able readily to find the R.A.M. The following is the rule:—

The *M.S.R.A. + Astronomical M.T. Ship = R.A.M. or Sidereal Time at Ship.
The A.S.R.A. + „ A.T. Ship = „ „ „ „

The rule may be more generally given thus:—The Right Ascension of *any* object + its Westerly hour angle = R.A.M.

It is usually sufficiently exact to work to the nearest minute. The elements required may be taken from *Brown's Nautical Almanac*.

*M.S.R.A., an abbreviation for Mean Sun's Right Ascension.

A.S.R.A., „ Apparent „ „

EXAMPLE I.

1904, January 20th, at 6h. 20m, a.m., M.T. Ship, in longitude 80° E. What is the R.A.M.?

	D.	H.	M.
Astronomical M.T. Ship,	19	18	20
Longitude in Time,	0	5	20
	<hr/>		
M.T.G.,	19	13	0
	<hr/>		

	H.	M.
M.S.R.A. or Sidereal Time at		
noon at Greenwich on 19th,	19	50
Acceleration for 13hrs.,	+	0 2
	<hr/>	
Correction M.S.R.A.,	19	52
Astronomical M.T. Ship,	18	20
	<hr/>	

When the sum exceeds 24hrs. reject the 24.

R.A.M., 14 12

EXAMPLE II.

1904, July 18th, at 7h. 28m. P.M., A.T. Ship, in longitude 153° E. What is the R.A.M.?

	D.	H.	M.
Astronomical A.T. Ship,	18	7	28
Longitude E., -	0	10	12
	<hr/>		
A.T.G.,	17	21	16
	<hr/>		

	H.	M.
A.S.R.A. at noon at Greenwich		
on 17th,	= 7	45
Correction 21h. 16m.,	+	0 4
	<hr/>	
Correction A.S.R.A.,	7	49
Astronomical A.T. Ship,-	7	28
	<hr/>	
R.A.M.,	15	17
	<hr/>	

If the Almanac is not handy, a rough estimate of the sun's R.A. can be made mentally by remembering that the sun's R.A. is 0 about the 22nd of March, increasing 2 hours per month, or about 4 minutes per day.

To find what Bright Stars are near the Meridian.

This may be easily done by inspection from the maps. Get the R.A.M. Find this meridian on one of the maps, and the stars lying near it will be those required. Those to the left will lie to the Eastward and are approaching, those to the right have crossed the meridian. In these problems it is hardly necessary to correct the sun's R.A.

EXAMPLE I.

1904, November 20th, at 1h. 0m. A.M., M.T. at Ship. Find what bright stars are near the meridian in latitude 48° N., longitude 30° W.

		H.	M.
M.T. Ship (Astronomical),		13	00
Approximate M.S.R.A.,	+	16	14
		<hr/>	
R.A.M.,		5	14
		<hr/>	

Look at map II. and note the meridian with R.A. 5 hours. The stars near it are—

Aldebaran to the West of the meridian and to the Southward of latitude.

Capella nearly on meridian and almost overhead.

Rigel nearly on meridian bearing South.

Bellatrix and *Betelgeuse* to the Eastward of the meridian, and to the Southward of the observer.

All the aforementioned stars are within 1 hour of the meridian. *Aldebaran* has already crossed, the others are approaching it.

A more extensive list of stars near the meridian can be taken from the Table of Stars (*see* page 4). Stars with R.A. near the R.A.M. are near the meridian. Those with R.A. LESS than R.A.M. are to the West of it, and those with GREATER R.A. are to the East of the meridian. The above R.A.M. 5h. 14m. (*see* Table of Stars on page 4), falls between the R.A. of *Rigel* and *Bellatrix*, both very close to the meridian.

Rigel and those immediately above are near the meridian to the West.

Bellatrix, , , below , , , East.

EXAMPLE II.

1904, June 11th, at 8h. 25m. P.M., A.T. at Ship, in latitude 30° S., longitude 120° W.

What bright stars are near the meridian?

		H.	M.
Astronomical A.T. Ship,		8	25
Approximate A.S.R.A.,		5	20
		<hr/>	
R.A.M.,		13	45
		<hr/>	

The stars near this meridian (*see* map IV.) are—

<i>Spica</i>	West of the meridian and to the Northward.
β <i>Centauri</i>	East ,, ,, Southward.
<i>Arcturus</i>	East ,, ,, Northward.
α <i>Centauri</i>	East ,, ,, Southward.

By looking at the Table of Stars for R.A. near 13h. 45m. the names of one or two more near the meridian may be seen.

To find the Time at which a Star will cross the Meridian.

For practical purposes at sea this can always be taken from tables. Most of the epitomes give tables of these, but those given in *Brown's Nautical Almanac* are corrected to date, and may be relied on as being accurate. In *Brown's Almanac* they are given for the 1st and every succeeding 5th day of each month. To find for any intermediate day, subtract 4 minutes for every day elapsed since the date given in the tables.

On the same page in *Brown's Almanac* the meridian passage (termed Southing in the table) of the four planets Venus, Mars, Jupiter, and Saturn, for every third day of each month is given. It is easy to estimate the meridian passage for an intermediate day by proportion. These are also given for every day in the Admiralty Almanac.

The meridian passage of a star or planet may be calculated by subtracting the sun's R.A. for the given date from that of the object.

Remarks on observing Star Altitudes.

In the actual observation of star altitudes the chief consideration is the visibility of the horizon line. The best time for taking an altitude is during twilight before sunrise or after sunset, when the horizon is clearly defined. The bright stars are so numerous that if the weather is clear there are always one or two that are in good position for observation during twilight, and the results obtained are in every way as reliable as if obtained

from altitudes of the sun. Indeed, the very best method in fixing a ship's position at sea (both latitude and longitude) is afforded by taking simultaneous altitudes of two stars, as will be explained later.

On moonlit nights also a good horizon may be obtained, but at other times some experience is required in order to judge of the reliability of the results. Constant practice will enable an observer to obtain good altitudes on dark clear nights, but at such times much will depend upon his keenness of vision, also the assistance of a good star telescope will then be useful. Efficiency, however, is only to be obtained by constant practice, and as experience is gained the observer will gradually get to know the amount of confidence that may be placed in an observation taken at any time.

At first beginners should practice the bringing of a star down to the horizon without using a telescope. Put the index at 0, and look through the telescope collar or ring and horizon glass direct at the star. Then gradually move the index along the arc, keeping the star's reflection in sight, and following it down until it reaches the horizon, when the index can be clamped and the contact made as perfect as possible. When meridian altitudes are required, it is easy to obtain the approximate altitude and clamp the index previous to observation; but, though this may be permissible at first, it is not recommended, as it is only applicable to stars when on the meridian.

Latitude by Meridian Altitude of a Star.

This is the simplest of all methods of finding the latitude of a ship at sea. If the altitude is correctly observed, the finding of the latitude simply involves the addition or subtraction of a few figures. The time or longitude is not required to be known, and no correction for declination is necessary. Its simplicity recommends it to beginners, who will naturally make a start in stellar navigation by taking meridian altitudes. There is a constant succession of bright stars passing the meridian at short intervals, which afford frequent opportunities for practice with the sextant, and at the same time aids the observer in identifying and recognising the bright stars. Opportunities should be sought

when the horizon is clear, and the results of several observations should be compared with each other, and also with the latitude by account. To know at what time the principal stars cross the meridian, the table giving the meridian passage of the stars may be consulted, and the star's approximate altitude computed for setting the sextant ready for observation.

Suppose that on March 11th, 1904, at about 7h. P.M., in latitude by arc $19^{\circ} 3' N.$, it was required to find what bright stars would next be available for observing their meridian altitude, and also to find the approximate altitude for setting the sextant ready for observation. Height of eye 24 feet.

In turning to the table in *Brown's Almanac* or Norie's epitome, it is seen that the star Sirius will cross the meridian on March 11th about 7h. 15m. P.M. apparent time. Its approximate meridian altitude may be computed as under, by working a meridian altitude backwards.

Lat. by acc.,	-	19	3	N.
Sirius decl.,	- -	16	35	S.
		<hr/>		
Mer. zen. dist.,	-	35	38	
		90	0	
		<hr/>		
Approx. mer. alt.,	- -	54	22	
Corr. for dip and ref. reversed, +		0	5	(Table XV., Norie.)
		<hr/>		
Approx. alt. for setting sextant, -		54	27	
		<hr/>		

The correction from Table XV., Norie, consists of the dip and refraction combined, which is always subtracted when computing the true altitude.

With the index clamped at this reading, the observer, a few minutes before the time of the star's meridian passage, knowing from the star's declination that it is to the South, looks at the horizon in this direction through the horizon glass, when the reflection of the star will be seen in the horizon glass, and a good contact can be made by the tangent screw. Repeat this process at short intervals until its meridian altitude is obtained.

Suppose the observer finds the observed meridian altitude of Sirius to be $54^{\circ} 22'$ bearing South, height of eye as before, the latitude is found as under:—

Obs. alt.,	-	-	54	22	S.
Corr. for dip and ref.,	-	0	5		(Table XV., Norie, or "Brown's Nautical Almanac.")
<hr/>					
True alt.,	-	-	54	17	
			90	0	
<hr/>					
Zenith dist.,	-	-	35	43	N.
Decl. of Sirius,	-	-	16	35	S.
<hr/>					
Latitude in,			19	8	N.
<hr/>					

It is a good plan to take the meridian altitudes of two stars that cross the meridian within a short time of each other, one bearing North and the other South. By comparing the results, the observer will be able to test the accuracy of his observations.

Latitude by Reduction to the Meridian.

In all ex-meridian problems time is an important factor. It is necessary that the correct time at ship (either mean or apparent) should be known. This may be found from a good watch whose error on apparent time at ship has been found from an observation of the sun during the day, or it may be obtained by applying the longitude in time to the mean time at Greenwich indicated by the chronometer. As, however, the observer may not have free access to a chronometer, the first method of finding the ship time will be used in the example shown here. Not only must the error of the watch be applied, but also a correction due to the difference of longitude made good since the error was determined, to be added if Easterly, and subtracted if Westerly. Stars near the zenith should not be used for this problem.

The Estimated Zenith Distance (E.Z.D.) is found by adding the latitude and Declination if they have different names, but by subtracting the less from the greater if they have the same name. The logs taken out to the first four decimals are sufficiently exact for practical purposes, but the sine of the half reduction should be taken out to the nearest second from the first pages of Table XXV., (Norie). Always add the reduction to the altitude; the result is then the meridian altitude which the star attains at the place of observation.

Latitude by Pole Star.

In Northern latitudes the Pole Star affords an easy method of finding the latitude. First, the R.A.M. or sidereal time at ship must be found.

Next, the star's true altitude must be obtained.

The latitude can then be found either by applying the corrections given in the tables at the end of the Nautical Almanac or by using the correction given in *Brown's Nautical Almanac*.

EXAMPLE.

1904, December 21st, at 1h. 27m. A.M., M.T. at ship, in longitude $148^{\circ} 54'$ W., the observed altitude of the Pole Star was $39^{\circ} 15'$, height of eye 24 feet. Find the latitude.

	D.	H.	M.		H.	M.					
M.T. ship, -	20	13	27	M.S.R.A. 20th, -	17	54 $\frac{1}{2}$	Obs. alt., -	-	39	15	N.
Long. in time W, +		9	56	Corr. for 23 ^h 23 ^m , -		4	Corr., -	-		6	
M.T.G., -	20	23	23	Corr. M.S.R.A.,	17	58 $\frac{1}{2}$	True alt., -		39	9	
				M.T. ship,	13	27	Const., -	-		1	
				R.A.M.,	7	25 $\frac{1}{2}$			39	8	
							Corr. I., -			0	
							Corr. II.,	+	0	$\frac{1}{2}$	
							Corr. III.,	+		1	
							Latitude, -	-	39	9 $\frac{1}{2}$	N.

Note.—These corrections are taken from the Naut. Almanac. Leaving out both the constant and Corr. III. can never make as much as one mile difference in the result, but do not omit one without also omitting the other.

Time Azimuths of Stars.

The stars offer a particularly useful and easy means of ascertaining the deviation of the compass at night by time azimuths. The altitude is not required, therefore it is immaterial whether the horizon is clear or not. It is only necessary that the compass bearing be correctly observed, and that the time of observation and the name of the star be known.

Stars are in the best position for azimuth when not more than about 30° from the horizon. Burdwood's Time Azimuth Tables (for latitudes 30° to 60° N. or S.) and Davis's (for latitudes 0° to 30° N. or S.) can be used for any star whose declination does not exceed 23° , by following the rules below. The observer who has studied the maps and directions in Part I. should have no difficulty in selecting a suitable star for these tables, and whenever an azimuth is required to be taken there are almost sure to be one or two in a good position for observation.

Before proceeding to work out an example it will be necessary to give the rules for finding a star's hour angle from the time at ship.

First find the R.A.M.

Under it place the star's R.A.; the difference between them is the star's hour angle. Then :—

If the R.A. has been subtracted from the R.A.M., name the angle hour W.

„ R.A.M. „ „ „ R.A. „ „ E.

If the hour angle should exceed 12 hours subtract it from 24 and change its name.

When using the tables always look for the star's hour angle in the column at the right hand margin of the page (under P.M.)

Always name the true azimuth the same as the latitude, and the same as the hour angle.

EXAMPLE.

1904, June 19th, at 1h. 20m. A.M., A.T. at Ship. Position by D.R. latitude 42° S., longitude 131° E.; the star β Ceti bore by compass E. $\frac{3}{4}$ N. Find the error and deviation of the compass for the course the ship was steering, the variation from the chart being 3° W.

					FROM BURDWOOD'S TABLES.	
A.T. ship,	D. 18	H. 13 M. 20	A.S.R.A. 18th, =	H. 5 M. 46	Lat., 42° S. Star's Decl., $18^{\circ}\frac{1}{2}$ S. ,, H.A., $5^h 32^m$ E.	True az., S. $80^{\circ}\frac{1}{2}$ E.
Long. E., -		8 44	Corr. for $4\frac{1}{2}$ hrs.,	1		180°
A.T. Green.,	18	4 36	A.T. ship,	13 20		
			R.A.M.,	19 7		True az., N. $99^{\circ}\frac{1}{2}$ E.
			Star's R.A.,	0 39		Obs. az., N. $81^{\circ}\frac{1}{2}$ E.
			Star's H. Angle, -	18 28 W.		Error, 18° E.
				24 0		Var., 3° W.
			Hour Angle,	5 32 E.		Dev., 21° E

Longitude by Chronometer from an Altitude of a Star.

The observer is supposed to be already familiar with the method of finding the longitude from an observation of the sun. When a star has been observed, its hour angle is calculated in the same manner as the sun's, after which, proceed as follows:—

If the hour angle is W., add it to the star's R.A.

If the hour angle is E., subtract it from 24 hours and then add to the star's R.A.*

The sum in either case will be the R.A.M.

From the R.A.M., + 24 hours if required, subtract the M.S.R.A. (corrected for the

M.T. Green.); the remainder is the M.T. ship. Prefix to it the astronomical date at ship; that is the same day as civil date if P.M., but previous day if A.M.

Under the M.T. ship place the M.T. Green.; their difference is the longitude in time which must then be changed into arc.

Stars nearest to the prime vertical should be chosen for finding longitude.

* In this rule the star's hour angle is supposed to have been taken from the top of the hour angle table.

1904, March 24th, A.M. at ship, in latitude $19^{\circ} 42'$ S., the observed altitude of the star α Bootis (Arcturus) after passing the meridian was $25^{\circ} 1'$, height of eye 24 feet. The astronomical time by chronometer was 23d. 11h. 44m. 36s., which was fast 2m. 17s. on M.T.G. Required the longitude.

If a planet's altitude is observed proceed exactly as above, using the planet's declination and right ascension, first correcting them for the mean time at Greenwich.

Ship's Position by Simultaneous Altitudes of Two Stars.

By observing the altitudes of two stars at twilight whilst the horizon is clear, it is possible to determine the ship's position with great accuracy. This is probably the best method of finding the position by observation, as the latitude and longitude can both be determined at once, without waiting (as must be done when the sun is observed) for the necessary change of bearing. In selecting two stars it must be noted that the nearer their bearings are to forming a right angle with each other the more reliable the result will be, and that stars very near the zenith should not be chosen.

The observer is supposed to be familiar with the method and principle of finding the ship's position from two altitudes of the sun with two assumed latitudes by Sumner's method. The same method might easily be applied to the simultaneous altitudes of two stars, but the general modern method is to assume one latitude only—*i.e.*, the latitude by D.R.—as a basis, and with it determine a longitude from each of the observations. If these two longitudes agree, it is the true longitude of the ship, and the latitude used is also the true latitude, and the ship's position is known without further calculation. Generally, however, the two longitudes will differ, proving that the latitude assumed is in error. It is evident that the greater the error in the assumed latitude, the greater will be the difference between the resulting longitudes. It is then necessary to find out how much the assumed latitude is in error, and thence obtain the true longitude. There are many ways in which this may be done. Johnson's method may be used with advantage, and can be recommended for practical use at sea.

Another good method is that in which the A and B tables are employed. For a full explanation of both these methods the observer is referred to the books specially dealing with them, which also contain the necessary tables. The purpose of this book will be best served by a worked example in which the true position is found by projection, as being more instructive, very simple, and forming a very good introduction to the study of the methods already mentioned. There are practically no rules to remember. The

true bearing of each star at the time of observation is obtained from the Azimuth Tables, the lines of position must be at right angles to these bearings, and the intersection of these lines of position, drawn through the corresponding points on the chart, must be the ship's position.

EXAMPLE.

1904, April 22nd, about 8h. 20m. P.M., M.T. at ship, position by D.R., latitude $42^{\circ} 10' N.$, longitude $11^{\circ} W.$, the following altitudes of two stars were taken simultaneously. Observed altitude of Sirius West of meridian $12^{\circ} 51'$; observed altitude of Arcturus East of meridian $36^{\circ} 56'$; height of eye 23 feet. The chronometer indicated 9h. 3m. 30s., M.T. Greenwich. Required the true position by observation.

Sirius, West of Meridian.

M.T.G.,	D.	H.	M.	S.	Star's R.A.,	H.	M.	S.
	-	22	9	3 30		6	40	55
M.S.R.A.,		H.	M.	S.	Decl.,	-	-	16 35 24 S.
		2	0	27				
Corr.	+		1	29				90 0 0
M.S.R.A.,		2	1	56	P.D.,	-	106	35 24
Alt.,	-	22	42		Star's W'ly H. angle,	H.	M.	S.
Lat.,		42	10	Sec. 0'13007	Star's R.A.,	3	38	20
P.D.,		106	35 $\frac{1}{2}$	Cosec. 0'01847	R.A.M.,	6	40	55
		2)171	27 $\frac{1}{2}$		M.S.R.A.,	10	19	15
		80	44	Cos. 9'20691	M.T. ship, 22nd,	2	1	56
		68	2	Sin. 9'96727	M.T. Green., 22nd,	8	17	19
		3 ^h 38 ^m 20 ^s		9'32272		-	9	3 30
							4)46	11

Longitude A, $11^{\circ} 32' 45'' W.$

With latitude $42^{\circ} N.$, declination $16\frac{1}{2}^{\circ} S.$, hour angle 3h. 38m. W., the true azimuth of Sirius from the tables is $S. 53^{\circ} W.$ The line of position must be at right angles to this, and therefore runs $N. 37^{\circ} W.$ and $S. 37^{\circ} E.$

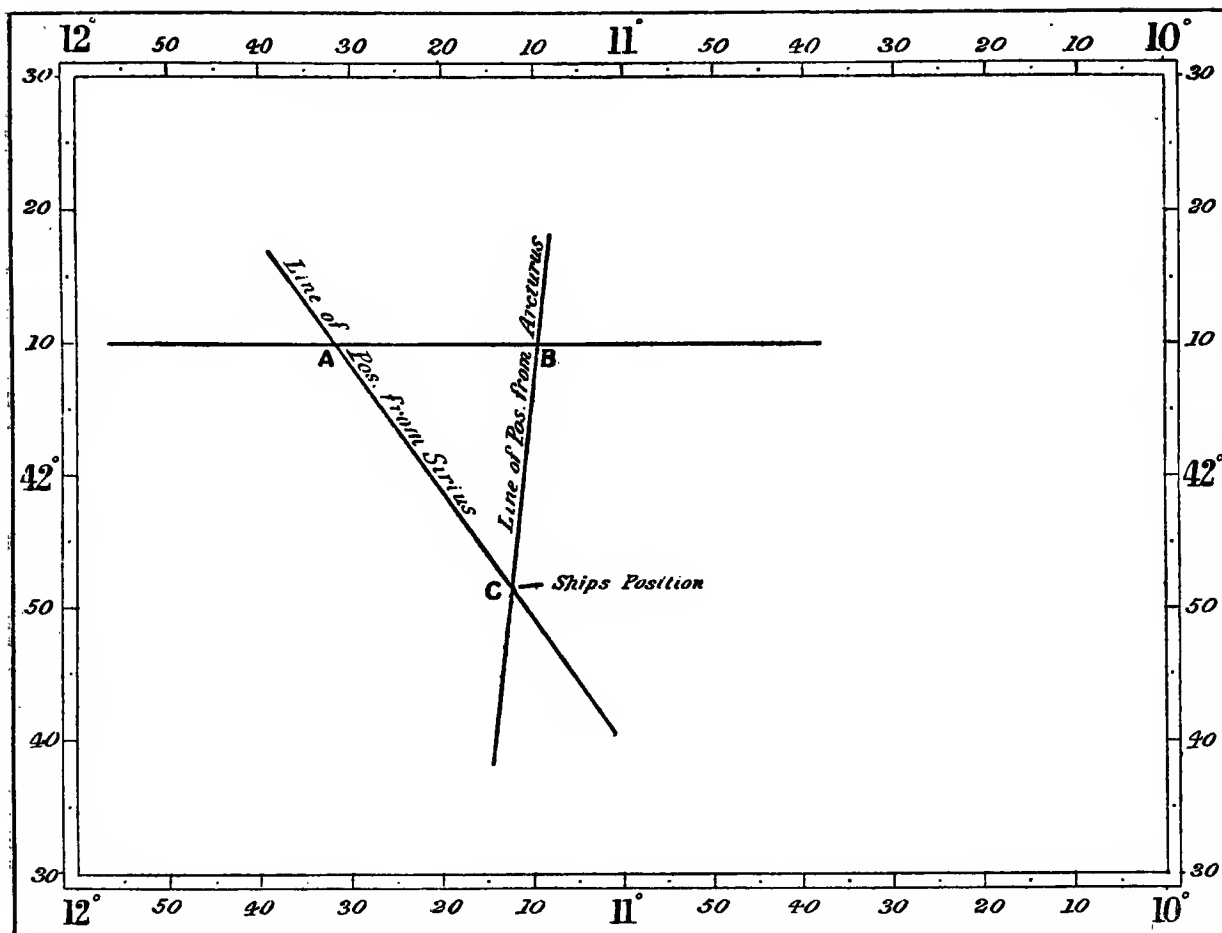
Mark the position of latitude $42^{\circ} 10' N.$, longitude $11^{\circ} 32\frac{3}{4}' W.$, on the chart, and through it draw a line of position as above (*see* line *AC* in the figure).

Arcturus, East of Meridian.

Star's R.A.,		H.	M.	S.
		14	11	19
Decl.,		-	19	40 49 N.
			90	0 0
P.D.,			70	19 11
Obs. alt.,		-	-	36 56
Corr.,		-	-	6
True alt.,				36 50
Star's E'ly H. angle,		-		H. M. S. 3 50 37
				24 0 0
Star's W'ly H. angle,				20 9 23
Star's R.A.,				14 11 19
R.A.M.,				10 20 42
M.S.R.A.,				2 1 56
M.T. ship,		22nd,		8 18 46
M.T.G.,		22nd,		9 3 30
				4)44 44
Longitude B.,				11 11 W.
Alt.,	36 50			
Lat.,	42 10	Sec	0.13007	
P.D.,	70 19	Cosec	0.02615	
Sum,	149 19			
Half,	74 39½	Cos	9.42255	
Rem.,	37 49½	Sin	9.78764	
	3 ^h . 50 ^m . 37 ^s .		9.36641	

With latitude 42° N., declination 20° N., hour angle 3h. 50m. E., the true azimuth of Arcturus from the tables is found to be S. 84° E. The corresponding line of position is therefore N. 6° E. and S. 6° W.

Mark the point B in latitude 42° 10' N., longitude 11° 11' W., on the chart, and through it draw this line of position. The point where it cuts the other line is the position of the ship.



Ship's true position, latitude $41^{\circ} 51\frac{1}{2}'$ N., longitude $11^{\circ} 14'$ W.

The simultaneous altitudes of a star and a planet, or of two planets, may be dealt with in a similar manner. When a planet is observed, its R.A. and declination must be corrected for the mean time at Greenwich.

If a star is observed whose declination exceeds 23° , its azimuth cannot be taken from Burdwood's or Davis's Tables, but it can be found by the A, B, and C Tables in Norie. Also the time azimuth tables do not give the azimuths where the altitude exceeds 60° .

SPECIAL CASE.—The work may be considerably abbreviated in the particular case when the star is on or near the meridian. The latitude should then be first calculated by meridian altitude or reduction to the meridian as the case may be. This latitude may then be used for finding the longitude by chronometer from the altitude of the other star.

when the horizon is clear, and the results of several observations should be compared with each other, and also with the latitude by account. To know at what time the principal stars cross the meridian, the table giving the meridian passage of the stars may be consulted, and the star's approximate altitude computed for setting the sextant ready for observation.

Suppose that on March 11th, 1904, at about 7h. P.M., in latitude by arc $19^{\circ} 3' N.$, it was required to find what bright stars would next be available for observing their meridian altitude, and also to find the approximate altitude for setting the sextant ready for observation. Height of eye 24 feet.

In turning to the table in *Brown's Almanac* or Norie's epitome, it is seen that the star Sirius will cross the meridian on March 11th about 7h. 15m. P.M. apparent time. Its approximate meridian altitude may be computed as under, by working a meridian altitude backwards.

Lat. by acc.,	-	-	-	19	3	N.
Sirius decl.,	-			16	35	S.
				<hr/>		
Mer. zen. dist.,	-			35	38	
				90	0	
				<hr/>		
Approx. mer. alt.,	-		-	54	22	
Corr. for dip and ref. reversed, +				0	5	(Table XV., Norie.)
				<hr/>		
Approx. alt. for setting sextant,				54	27	
				<hr/>		

The correction from Table XV., Norie, consists of the dip and refraction combined, which is always subtracted when computing the true altitude.

With the index clamped at this reading, the observer, a few minutes before the time of the star's meridian passage, knowing from the star's declination that it is to the South, looks at the horizon in this direction through the horizon glass, when the reflection of the star will be seen in the horizon glass, and a good contact can be made by the tangent screw. Repeat this process at short intervals until its meridian altitude is obtained.

Suppose the observer finds the observed meridian altitude of Sirius to be $54^{\circ} 22'$ bearing South, height of eye as before, the latitude is found as under:—

Obs. alt.,	-	-	-	54	22	S.
Corr. for dip and ref.,	-	0	5	(Table XV., Norie, or "Brown's Nautical Almanac.")		
<hr/>						
True alt.,	.			54	17	
				90	0	
<hr/>						
Zenith dist.,	-			35	43	N.
Decl. of Sirius,	-			16	35	S.
<hr/>						
Latitude in,				19	8	N.
<hr/>						

It is a good plan to take the meridian altitudes of two stars that cross the meridian within a short time of each other, one bearing North and the other South. By comparing the results, the observer will be able to test the accuracy of his observations.

Latitude by Reduction to the Meridian.

In all ex-meridian problems time is an important factor. It is necessary that the correct time at ship (either mean or apparent) should be known. This may be found from a good watch whose error on apparent time at ship has been found from an observation of the sun during the day, or it may be obtained by applying the longitude in time to the mean time at Greenwich indicated by the chronometer. As, however, the observer may not have free access to a chronometer, the first method of finding the ship time will be used in the example shown here. Not only must the error of the watch be applied, but also a correction due to the difference of longitude made good since the error was determined, to be added if Easterly, and subtracted if Westerly. Stars near the zenith should not be used for this problem.

EXAMPLE.

1904, December 20th, P.M. at ship, in latitude by account $13^{\circ} 32' N.$, longitude $86^{\circ} 36' E.$, the observed altitude of the star Canopus when near the meridian was $23^{\circ} 24'$, South of observer, height of eye 22 feet. The time by watch was 11h. 58m. 22s., which had been found during the day to be 5m. 6s. fast on apparent time at ship, and since this error was found the ship had made 13' difference of longitude to the Eastward. Required the latitude.

D. long. since error was found— 13' E. 4 in time = 52 secs.	Time by watch, fast —	D. H. M. S. - 20 11 58 22 5 6	A.S.R.A. for Dec. 20, = 17 52 11*	H. M. S. 17 52 11*
Long., $86^{\circ} 36'$ 4 6.0)34.6 24 in time = $5^h 46^m 24^s$	D. long. E., Appt. time ship, Long. E. Appt. time Green.,	+ - 20 11 54 8 - 5 46 24 20 6 7 44	Correct R.A., A.T. ship, - R.A.M., R.A. star, Hour Angle of Canopus,	17 53 19 11 54 8 - 5 47 27 6 21 53 34 26 E.
Var. 1 hour of Sun's R.A. 11' 10 6' 1 11 10 6660 6.0)67.7 10 1 ^m . 8 ^s	Obs. alt., Corr., True alt., Red., - Merid. alt., Zen. dist., Decl., - Latitude,	- 23 24 S. - 7 23 17 + 25 23 42 - 66 18 N. 52 38½ S. - 13 39½ N.	Hour angle, Lat. by acc., Decl., E.Z.D., ½ Red., 2 24 58	Log 7.7508 (XXXI. Norie.) Cos 9.9878 Cos 9.7830 Cosec 10.0387 Sine 7.5603

* Work Time and Right Ascension to seconds in this problem.

The Estimated Zenith Distance (E.Z.D.) is found by adding the latitude and Declination if they have different names, but by subtracting the less from the greater if they have the same name. The logs taken out to the first four decimals are sufficiently exact for practical purposes, but the sine of the half reduction should be taken out to the nearest second from the first pages of Table XXV., (Norie). Always add the reduction to the altitude; the result is then the meridian altitude which the star attains at the place of observation.

Latitude by Pole Star.

In Northern latitudes the Pole Star affords an easy method of finding the latitude.

First, the R.A.M. or sidereal time at ship must be found.

Next, the star's true altitude must be obtained.

The latitude can then be found either by applying the corrections given in the tables at the end of the Nautical Almanac or by using the correction given in *Brown's Nautical Almanac*.

EXAMPLE.

1904, December 21st, at 1h. 27m. A.M., M.T. at ship, in longitude 148° 54' W., the observed altitude of the Pole Star was 39° 15', height of eye 24 feet. Find the latitude.

M.T. ship,	D. H. M.	M.S.R.A. 20th,	H. M.	Obs. alt.,	-	-	39 15 N.
Long. in time W, +	20 13 27	Corr. for 23 ^h 23 ^m , -	17 54½	Corr.,	-	-	6
M.T.G., -	9 56	Corr. M.S.R.A., -	4	True alt.,	-	-	39 9
	20 23 23	M.T. ship, -	17 58½	Const.,	-	-	1
		R.A.M.,	13 27		-	-	39 8
			7 25½	Corr. I.,	-	-	0
				Corr. II.,	-	+	0½
				Corr. III.,	-	+	1
				Latitude, -	-	-	39 9½ N.

Note.—These corrections are taken from the Naut. Almanac.

Leaving out both the constant and Corr. III. can never make as much as one mile difference in the result, but do not omit one without also omitting the other.

Time Azimuths of Stars.

The stars offer a particularly useful and easy means of ascertaining the deviation of the compass at night by time azimuths. The altitude is not required, therefore it is immaterial whether the horizon is clear or not. It is only necessary that the compass bearing be correctly observed, and that the time of observation and the name of the star be known.

Stars are in the best position for azimuth when not more than about 30° from the horizon. Burdwood's Time Azimuth Tables (for latitudes 30° to 60° N. or S.) and Davis's (for latitudes 0° to 30° N. or S.) can be used for any star whose declination does not exceed 23° , by following the rules below. The observer who has studied the maps and directions in Part I. should have no difficulty in selecting a suitable star for these tables, and whenever an azimuth is required to be taken there are almost sure to be one or two in a good position for observation.

Before proceeding to work out an example it will be necessary to give the rules for finding a star's hour angle from the time at ship.

First find the R.A.M.

Under it place the star's R.A.; the difference between them is the star's hour angle. Then :—

If the R.A. has been subtracted from the R.A.M., name the angle hour W.

„ R.A.M. „ „ R.A. „ „ E.

If the hour angle should exceed 12 hours subtract it from 24 and change its name.

When using the tables always look for the star's hour angle in the column at the right hand margin of the page (under P.M.)

Always name the true azimuth the same as the latitude, and the same as the hour angle.

EXAMPLE.

1904, June 19th, at 1h. 20m. A.M., A.T. at Ship. Position by D.R. latitude 42° S., longitude 131° E.; the star β Ceti bore by compass E. $\frac{3}{4}$ N. Find the error and deviation of the compass for the course the ship was steering, the variation from the chart being 3° W.

			FROM BURDWOOD'S TABLES.		
A.T. ship,	D. 18	H. M. 13 20	A.S.R.A. 18th, =	H. M. 5 46	
Long. E., -		8 44	Corr. for 4½ hrs.,	I	Lat., - 42° S. } True az., S. 80°½ E.
A.T. Green.,	18	4 36	A.T. ship,	13 20	Star's Decl., 18°½ S. } 180°
			R.A.M.,	19 7	„ H.A., 5h. 32m E. } True az., N. 99°½ E.
			Star's R.A.,	0 39	Obs. az., N. 81°½ E.
			Star's H. Angle, -	18 28 W.	Error, 18° E.
				24 0	Var., 3° W.
			Hour Angle,	5 32 E.	Dev., 21° E

Longitude by Chronometer from an Altitude of a Star.

The observer is supposed to be already familiar with the method of finding the longitude from an observation of the sun. When a star has been observed, its hour angle is calculated in the same manner as the sun's, after which, proceed as follows:—

If the hour angle is W., add it to the star's R.A.

If the hour angle is E., subtract it from 24 hours and then add to the star's R.A.*

The sum in either case will be the R.A.M.

From the R.A.M., + 24 hours if required, subtract the M.S.R.A. (corrected for the M.T. Green.); the remainder is the M.T. ship. Prefix to it the astronomical date at ship; that is the same day as civil date if P.M., but previous day if A.M.

Under the M.T. ship place the M.T. Green.; their difference is the longitude in time which must then be changed into arc.

Stars nearest to the prime vertical should be chosen for finding longitude.

* In this rule the star's hour angle is supposed to have been taken from the top of the hour angle table.

EXAMPLE.

1904, March 24th, A.M. at ship, in latitude $19^{\circ} 42' S.$, the observed altitude of the star α Bootis (Arcturus) after passing the meridian was $25^{\circ} 1'$, height of eye 24 feet. The astronomical time by chronometer was 23d. 11h. 44m. 36s., which was fast 2m. 17s. on M.T.G. Required the longitude.

Chronometer Time,	D. 23 H. 11 M. 44 S. 36	Star's decl.,	- 19 41 N.
Fast,	- - 2 17		90 0
M.T.G., -	<u>23 11 42 19</u>	Polar dist.,	<u>109 41</u>
Obs. alt., -	25 1	Alt.,	24 54
Diff. and Ref.,	- 7	Lat. 19 42	Sec. 10'02619
True alt.,	<u>24 54</u>	P.D., 109 41	Cosec. 10'02615
		2)154 17	
M.S.R.A. 23rd,	H. 0 M. 2 S. 11	$\frac{1}{2}$ sum 77 8 $\frac{1}{2}$	Cos. 9'34741
Corr. 11 ^h . 42 ^m .	- 1 55	Rem., 52 14 $\frac{1}{2}$	Sin. 9'89796
Correct M.S.R.A.,	<u>0 4 6</u>		<u>9'29771</u>
Star's W'ly H. angle,	H. 3 M. 31 S. 39		
Star's R.A., -	<u>14 11 18</u>		
R.A.M., - -	17 42 57		
M.S.R.A.,	<u>0 4 6</u>		
M.T. ship, 23rd, -	17 38 51		
M.T. Green., 23rd,	<u>11 42 19</u>		
	5 56 32		
	<u>60</u>		
	4)356 32		
	<u>Longitude 89 8 E.</u>		

If a planet's altitude is observed proceed exactly as above, using the planet's declination and right ascension, first correcting them for the mean time at Greenwich.

Ship's Position by Simultaneous Altitudes of Two Stars.

By observing the altitudes of two stars at twilight whilst the horizon is clear, it is possible to determine the ship's position with great accuracy. This is probably the best method of finding the position by observation, as the latitude and longitude can both be determined at once, without waiting (as must be done when the sun is observed) for the necessary change of bearing. In selecting two stars it must be noted that the nearer their bearings are to forming a right angle with each other the more reliable the result will be, and that stars very near the zenith should not be chosen.

The observer is supposed to be familiar with the method and principle of finding the ship's position from two altitudes of the sun with two assumed latitudes by Sumner's method. The same method might easily be applied to the simultaneous altitudes of two stars, but the general modern method is to assume one latitude only—*i.e.*, the latitude by D.R.—as a basis, and with it determine a longitude from each of the observations. If these two longitudes agree, it is the true longitude of the ship, and the latitude used is also the true latitude, and the ship's position is known without further calculation. Generally, however, the two longitudes will differ, proving that the latitude assumed is in error. It is evident that the greater the error in the assumed latitude, the greater will be the difference between the resulting longitudes. It is then necessary to find out how much the assumed latitude is in error, and thence obtain the true longitude. There are many ways in which this may be done. Johnson's method may be used with advantage, and can be recommended for practical use at sea.

Another good method is that in which the A and B tables are employed. For a full explanation of both these methods the observer is referred to the books specially dealing with them, which also contain the necessary tables. The purpose of this book will be best served by a worked example in which the true position is found by projection, as being more instructive, very simple, and forming a very good introduction to the study of the methods already mentioned. There are practically no rules to remember. The

EXAMPLE.

Sirius, West of Meridian.

Longitude A, $11^{\circ} 32' 45''$ W.

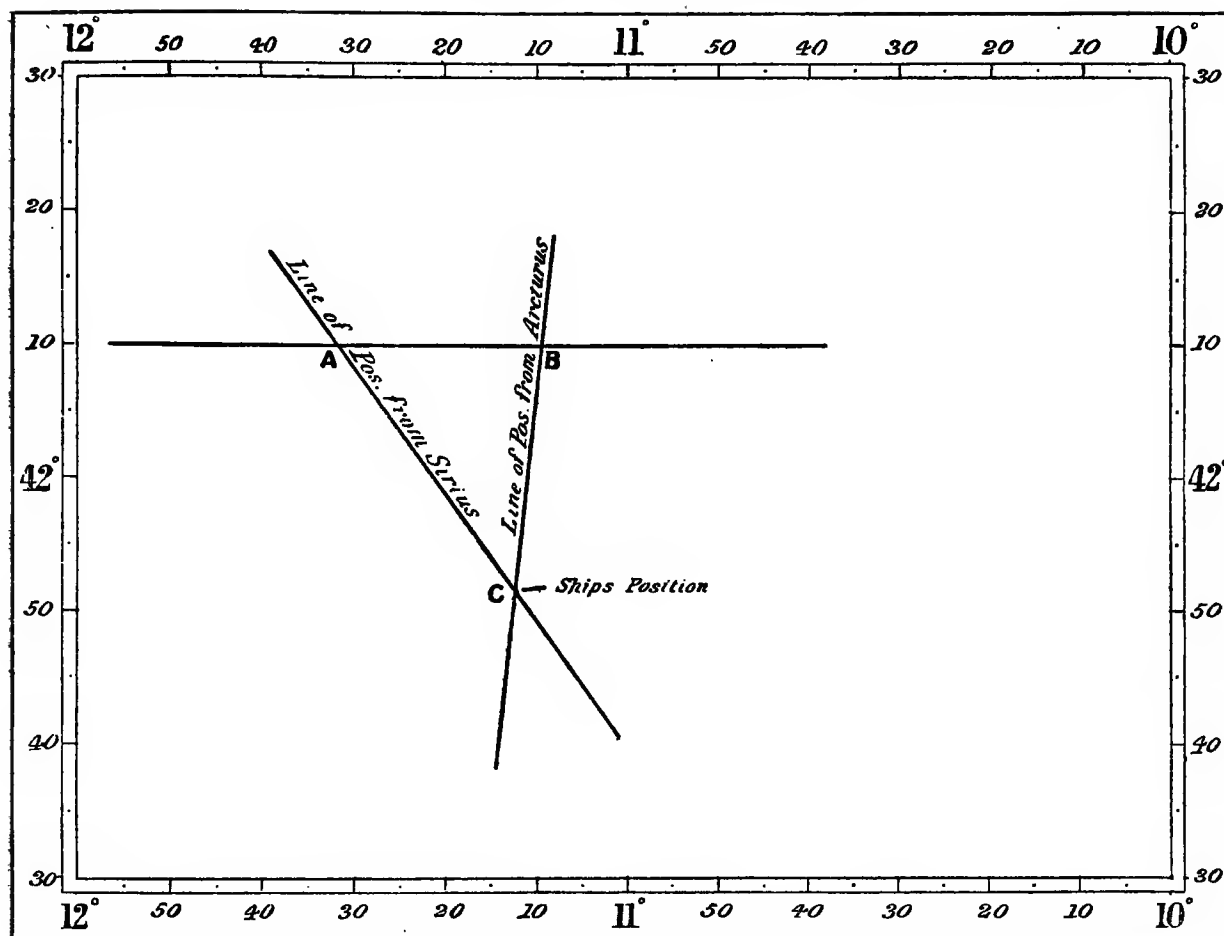
Mark the position of latitude $42^{\circ} 10' \text{ N.}$, longitude $11^{\circ} 32\frac{3}{4}' \text{ W.}$, on the chart, and through it draw a line of position as above (*see* line *AC* in the figure).

Arcturus, East of Meridian.

Star's R.A.,		H.	M.	S.
		14	11	19
Decl.,		°	'	"
		19	40	49 N.
		90	0	0
P.D.,		70	19	11
Obs. alt.,		-	-	° ' 36 56
Corr.,		-	-	6
True alt.,				36 50
Star's E'ly H. angle,		-	-	H. M. S. 3 50 37
				24 0 0
Star's W'ly H. angle,				20 9 23
Star's R.A.,				14 11 19
R.A.M.,				10 20 42
M.S.R.A.,				2 1 56
M.T. ship,		22nd,		8 18 46
M.T.G.,		22nd,		9 3 30
				4)44 44
Longitude B.,				11 11 W.
Alt.,	36 50			
Lat.,	42 10	Sec	0.13007	
P.D.,	70 19	Cosec	0.02615	
Sum,	- 149 19			
Half,	74 39½	Cos	9.42255	
Rem.,	37 49½	Sin	9.78764	
	3 ^h 50 ^m 37 ^s		9.36641	

With latitude 42° N., declination 20° N., hour angle 3h. 50m. E., the true azimuth of Arcturus from the tables is found to be S. 84° E. The corresponding line of position is therefore N. 6° E. and S. 6° W.

Mark the point B in latitude 42° 10' N., longitude 11° 11' W., on the chart, and through it draw this line of position. The point where it cuts the other line is the position of the ship.



Ship's true position, latitude $41^{\circ} 51\frac{1}{2}'$ N., longitude $11^{\circ} 14'$ W.

The simultaneous altitudes of a star and a planet, or of two planets, may be dealt with in a similar manner. When a planet is observed, its R.A. and declination must be corrected for the mean time at Greenwich.

If a star is observed whose declination exceeds 23° , its azimuth cannot be taken from Burdwood's or Davis's Tables, but it can be found by the A, B, and C Tables in Norie. Also the time azimuth tables do not give the azimuths where the altitude exceeds 60° .

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